

VIII. *Total Eclipse of the Sun, 1896.—The Novaya-Zemlya Observations.*

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Communicated by J. NORMAN LOCKYER, C.B., F.R.S.

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[PLATES 1, 2.]

1. As the observations of the total eclipse of the sun in 1896, made in Novaya-Zemlya by the “Otaria” expedition, are the only British observations of that eclipse which secured successful results, it may be of some importance to detail the conditions under which those observations were made.

2. On learning that the Government funds available for the observation of the total eclipse of 1896 would not suffice for more than the parties detailed to Japan and to Norway, I willingly offered to take another party to Novaya-Zemlya in my yacht “Otaria.”

3. It would thus be possible to increase the chances of a clear view of the eclipse ; and the altitude of the sun at the time of the eclipse would be far greater in Novaya-Zemlya than on the Varanger Fjord.

Personally, I also formed high hopes as to results (especially photographic results) at a latitude far higher than any at which such powerful astronomical instruments had before been used.

4. I received and carefully stowed on the yacht instruments of various kinds ; some selected by Mr. NORMAN LOCKYER, with the approval of the Lords of Committee of Council on Education, from among those in the Solar Physics Observatory ; and others by Mr. E. J. STONE, by special consent of the Trustees, from the instruments at the Radcliffe Observatory.

5. I had the good fortune to receive as my guests Mr. E. J. STONE, M.A., F.R.S., the Radcliffe Observer ; Mr. W. SHACKLETON, F.R.A.S., one of the staff under the Solar Physics Committee ; and Lieutenant VERNON BROOKE WEBB, R.N.

The late Prince LOBANOFF, through our ambassador at St. Petersburg, and at the request of the Foreign Office, was good enough to supply information for me, and to give special instructions to the officials of the Archangel Province to render every aid and assistance to our expedition.

6. We left Dundee on the 18th July, but were much delayed by persistent calms. Nevertheless we arrived safely off the coast of Novaya-Zemlya on the 2nd August.

7. At the small new Samoyede settlement of Karmakul we found two observing parties from Russia, constituted as follows :—

Imperial Academy of Science Party.

Prince BORIS GALITZINE (Leader)		Physics.
M. BACKLUND (Director, Pulkova)		Astronomy.
M. KOSTINSKEY (Pulkova)		„
M. HANSKY	„	„
M. GOLDENING		Photography.
M. JACOBSON		Zoology.

Kasan University Party.

M. DUBIAGO		Astronomy.
M. GOLDHAMMER		Physics.
M. ZEIGEL		„
M. KRASNOFF		Astronomy.
M. BELKBUTCH		Zoology.
M. BARANSVITCH		Photography.

8. The Russians had established their observation huts and instruments on rising ground, perhaps 60 feet above the sea-level, with barren undulating tundra, culminating two to three miles inland in a long range of hills, say 1500 feet to 2000 feet in altitude. We entered into friendly relations with them.

9. We decided on making our observation spot as far to the westward as possible, hoping thus to eliminate all chance of obstruction by clouds gathering on these inland hills.

We selected a site on an island, about 20 feet above sea-level, the strata being laminous slate, with an almost perpendicular upheaval. A bluff, some 30 feet high, protected the camp from seawards, but all was open to the eastward.

The precise position of the camp was—

Lat. $72^{\circ} 22' 40''$ N.
Long. $52^{\circ} 38' 13''$ E.

This position was verified by Lieutenant WEBB by measurement from one of the Russian triangulation points—a beacon—about a mile distant, the latitude and longitude of which were supplied by the Russian observers.

10. We erected shelter tents of spars and sails and set up the Willesden canvas huts for the 12" Cooke siderostat, two large spectrum and one corona photograph telescopes.

11. Mr. STONE, with the aid of Lieutenant WEBB, used a small but powerful equatorial (presented to the Radcliffe Trustees by FRANCES ANNE, Dowager Duchess of Marlborough).

The spectroscope was one made, from Mr. STONE's plans, specially for the eclipse by Mr. HILGER. The dispersion in the photographic camera consisted of a direct spectroscope, capable of separating the D lines, and a prism of crown glass of 60°. The light reflected from the surface of the prism was used for a second direct spectroscope, and the instrument, therefore, admitted of combined eye and photographic spectrum observations.

12. Mr. SHACKLETON worked with a prismatic camera of 3 inches aperture with two prisms of 60°, using the siderostat, and also a direct vision slitless spectroscope, by means of which he was enabled to signal with exactness the disappearance of the continuous spectrum.

13. I took charge of the coronagraph provided by Mr. LOCKYER. The telescope was one of $4\frac{5}{8}$ inches aperture and 6 feet 9 inches focal length. The object glass was not new, and decidedly green in tint, but it was the only one available for the expedition. The size of the image was 0.76 inch, and the ratio of aperture to focal length was $\frac{1}{17.5}$.

The telescope was mounted in a N. and S. direction immediately above the prismatic camera, so that both could use the one siderostat. Mr. SHACKLETON, with commendable care and trouble, finally secured admirable adjustments of all these instruments.

14. Meteorological observations were made by means of a self-registering barometer and thermometer and a sympiesometer.

Lady BADEN-POWELL and the yacht's crew were detailed to make drawings of what they could see of the *outer corona*, on printed diagram plans designed by Mr. STONE, and to note the position of any "stars" seen, and otherwise observe general aspects.

15. Everything was ready well in time, and throughout the eclipse all proceeded most satisfactorily. In all, twenty-nine good photographs were secured.

16. The local *times* of commencement and end of totality were noted by the sailing-master of the "Otaria"—Captain G. WILLCOX—as being 7^h 34^m 54^s and 7^h 36^m 44^s respectively, but there was some doubt as to the signal for the end of totality. Captain WILLCOX also gave out the number of passing seconds, by chronometer, for the information of the observers.

17. With regard to the *spectroscopic* results obtained, both by Mr. STONE and Mr. SHACKLETON, I am informed that they promise to be of the highest scientific value; they are now being worked out by Mr. STONE and Mr. NORMAN LOCKYER respectively, but the final elucidation will naturally occupy some considerable time.

In all, four good photographs were secured by the slit and nineteen by the prismatic camera.

18. With regard to the results secured by the *coronagraph*, the following statements may be made :—

Assuming observations on the central line the following scheme of exposures had been prepared by Mr. LOCKYER :—

No.	Exposure.	Change of plates.
	seconds.	seconds.
1	5	5
2	15	5
3	60	5
4	2	5
5	18	5

As the station we took up in Novaya Zemlya was about twenty miles from the central line, our period of totality was reduced to 1 minute 45·5 seconds, and Mr. SHACKLETON drew up the following revised scheme :—

No.	Exposure.	Change of plates.
	seconds.	seconds.
1	5	5
2	15	5
3	40	5
4	2	5
5	15	5

With the aid of the mate of the “Otaria,” Mr. KERLEY, I successfully made the exposures at the regulated times. The “Castle” plates, by MAWSON and SWAN, were used throughout. Five photographs of the corona were taken, with the following exposures :—

No.	Exposure.
	seconds.
1	5
2	15
3	40
4	2
5	15

The four plates exposed during totality were developed by Mr. SHACKLETON before leaving Novaya Zemlya, and the fifth at South Kensington about five weeks later.

Mr. LOCKYER has been good enough to have these enlarged at the Solar Physics Observatory, by Corporal HASLAM, R.E., and I have the pleasure of laying them before the Society (see Plate 1). It will be seen (by reference to 'Phil. Trans.,' 1889, vol. 180, pp. 291, &c.) that the expected agreement with the corona of 1886 is most marked.

The field of view of the telescope employed was circular, with an approximate diameter of 100 minutes of arc. In the longer exposed photographs the longest streamer is cut off by the boundary of the field at 1·06 of the moon's diameter. As seen visually the streamer was estimated to have a length of 1·76 of the diameter.

19. It should be noted that the other heavenly bodies seen and located by "Otaria" observers during totality were the planets *Mercury*, *Jupiter*, *Venus*, and *Mars*, and the star *Regulus*. The several independent sketches on plans, by eye, of the corona, coincided remarkably with the photographs.

I would add that during totality the darkness was not sufficient to interfere with the reading of the chronometer in the open, or of a BENSON'S chronograph inside the telescope hut. The atmosphere may possibly have been lighted up by the large areas of snow-covered land in our neighbourhood.

20. The *Meteorological* observations made at the time were significant.

(1.) The self-registering (NEGRETTI and ZAMBRA) thermometer, placed in sunlight, indicated remarkable changes of temperature, ranging, during the period of the eclipse, from 47° Fahrenheit down to 36°, and rising, within three hours after totality, to the maximum for the day of no less than 62°.

(2.) The self-registering barometer (NEGRETTI and ZAMBRA), as will be seen by the accompanying photographic enlargement (not reproduced here), gave no indications except those of unevenness.

But readings, at necessarily irregular intervals, of the sympiesometer (NEGRETTI and ZAMBRA), before and after totality, gave the following results :—

Local time.		Thermometer.	Barometer.	
hrs.	mins.	°		
7	13	49	30	3.25
7	18	48	30	3.30
7	20	47.5	30	3.30
7	20	46.3	30	3.18
Interval of totality.				
7	39	35.3	30	3.15
7	47	46	30	3.25

(3.) The wind was blowing moderately (BEAUFORT scale, 3 to 4) all the morning from about N. by E., some cirrus clouds gradually coming up from E.N.E. Just before totality there was a sudden change of wind to E.N.E. Several present, myself among the number, distinctly noticed that the wind died away during the totality.

21. All members of the "Otaria" party did everything in their power to make the observations a success; and thus full advantage was taken of the opportunities afforded by a happily clear view of the sun.

22. While it is cause for great regret that similar opportunities were not afforded to the skilled observers in Norway and Japan—or, indeed, at the other stations—it is highly satisfactory to know that the total eclipse of 1896 was most successfully observed at one British station, and that the results thus secured will be of high value to astronomical science.

ON THE PHOTOGRAPHS OF THE CORONA OBTAINED IN NOVAYA-ZEMLYA. BY W. H. WESLEY.

The drawing, of which Plate 2 is a Woodburytype reproduction, was made from four negatives taken by Sir G. BADEN-POWELL and Mr. SHACKLETON. The moon's diameter is $\frac{8}{16}$ inch on the original negatives, and the drawing has been enlarged to a scale of $2\frac{1}{2}$ inches for the moon's diameter. The following are the particulars of the plates:—

Plate 1. Exposure, 5 seconds. Shows a faint fringe of corona on the W., and a greater extent on the E., where it reaches a height of 5' or 6'. Plate very clean and definition good; the lower details on the E. limb extremely well seen; background of sky quite clear.

Plate 2. Exposure, 15 seconds. Very fine negative. Corona extends to about half a lunar diameter on the E., and more than half as far on the W., but the conspicuous ray to the N.W. is easily traced for a diameter from the limb, where it is cut

off by the boundary of the field. Near the limb the corona is very intense, but sufficiently transparent to allow the low details to be easily made out. Sky slightly fogged.

Plate 3. Exposure, 40 seconds. Very fine negative. Sky decidedly more fogged than in Plate 2, but corona very well defined, extending on the E. to about 21' from the limb, and on the W. to 16'. The ray on the N.W. is cut off by the boundary of the field. Although the corona is very dense near the limb, the low details can be made out very well with suitable illumination.

Plate 4. Exposure, 2 seconds. Clear negative; shows prominences very well, but only a narrow, faint fringe of corona, more intense on the S.W. and almost invisible at the N. pole. Only a little of the lowest detail is shown.

The negatives appear well-focussed and the grain of the plates is fine, so that I have been able to make out much more of the lower details than in most recent eclipse photographs.

The corona of 1896 is remarkably symmetrical about the sun's axis; still more so than that of 1886, which it closely resembles. The northern polar rift is extremely well-marked; it extends for about 40° along the limb, and is filled with fine rays, attaining a height of about 11'; straight and nearly radial in the centre, and becoming more curved and inclined from the axis towards either side of the rift. As in 1886, the southern rift extends for a greater distance along the limb, but is much less distinct than the north polar rift, the rays filling it being broader and more diffused, and its boundaries less clearly defined.

The conspicuous ray (or group of rays) in the N.W. quadrant, mentioned in the description of the plates, bounds the N. polar rift to the W. with a decided curve of double curvature, similar to that shown in 1885. It shows indications of synclinal structure, but not so clearly as in 1886. On the small scale negative, taken by Dr. HANSKY, of the Russian Expedition, this ray is shown tapering to a point and then slightly widening again, attaining a height of more than two diameters. At the base of this ray is a prominence, as in the corresponding ray of 1886. Immediately to the S. of this great ray is a well-marked opening in the corona, filled with three narrow, nearly radial rays. A sharp, narrow rift separates these from the somewhat inconspicuous equatorial group, within which two rays seem abruptly bent aside in an equatorial direction, and at the base are indications of small rays completely bending over. South of the equatorial group are two conical masses, showing distinct traces of synclinal structure. The southern of these masses is the larger, and forms the western boundary of the great southern rift. With the exception of the great N.W. ray, which extends further than any part of the corona, the western side is less conspicuous and extensive than the eastern, and shows less detail near the limb.

On the eastern side the north polar rift is bounded by a large mass, composed of broad rays showing some tendency to synclinal curves. The edge which bounds the rift is much inclined from the radial in an equatorial direction, and is more sharply

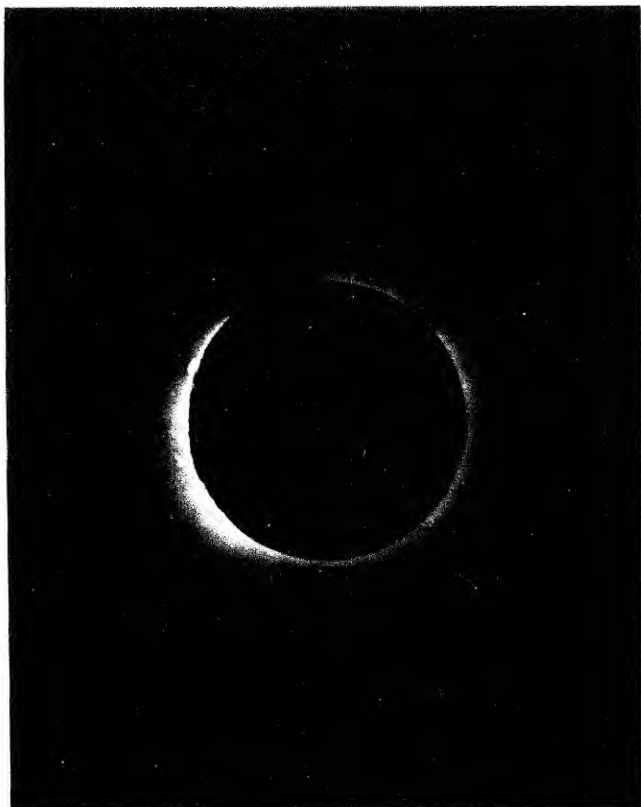
defined than any other coronal feature. A large prominence (about latitude 45°) is at the base of the group; there is a decided thinning of the corona around it, and the lower rays, to a height of about $3'$, appear to bend over the prominence.

A broad V-shaped opening, partly filled up with rays, separates the N.E. from the E. equatorial group. This is very large, reaching a greater height than any other portion of the corona (except the N.W. ray), and extending along the limb to about latitude 45° S., after which the group breaks up into a succession of broad rays curving away from the S. pole, and forming the eastern portion of the S. polar rift. The detail on the eastern side of the corona is extremely complex and interesting, but a few points only can be noted. A small hook-shaped ray, about $2\frac{1}{2}'$ high, springs from a small prominence (about 18° N. latitude), and is distinctly bounded by a narrow dark space or outline. A large double-headed prominence (latitude about 5° N.) is similarly outlined—the outline exactly following its contours. Apparently standing upon this prominence is a singular, dark, elliptical ring, about $2\frac{1}{2}'$ by $2'$, its longer axis nearly radially directed. From the top of the ring rises a thin, tapering ray, curved towards the south. South of the bright prominence are small rays which appear cut across by dark veins at heights of $2'$ and $3'$ from the limb. Further south the great mass is broken up in a manner entirely unusual. The solar corona usually appears composed of overlapping rays emanating from the sun, but here it appears to be also broken up by dark channels into flocculent-looking masses, giving to it somewhat of the *curdled* appearance of some parts of the nebula in *Orion*. The great mass is roughly divided into a northern and southern portion by an irregular gap or dark stream, commencing at the top of a mass of rays about $6'$ from the limb; this gap turns towards the north, then curves east, and is lost at a height of about $17'$. The base of the equatorial mass is filled by rays having much contorted forms. It is impossible to resist the impression that this portion of the corona is torn by violent storms or perturbations.

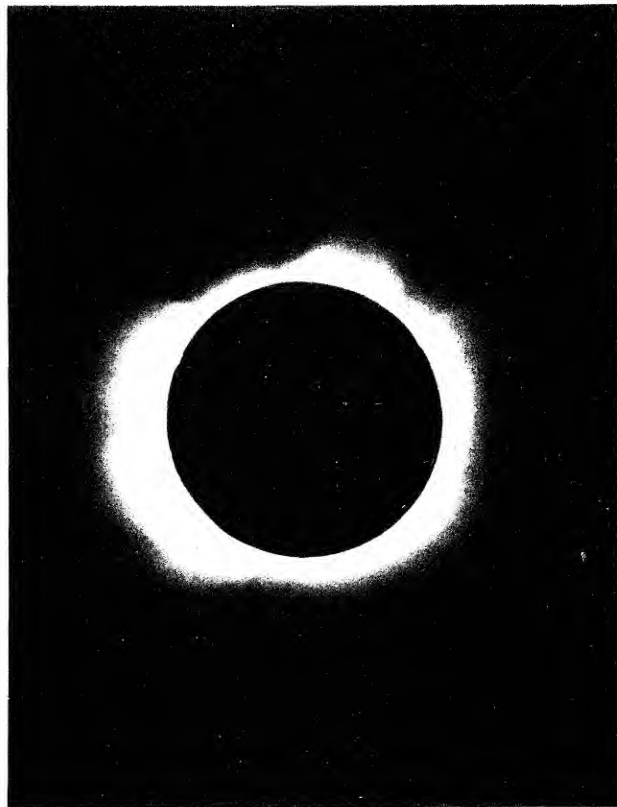
Conclusions.

1. The remarkable resemblance of the corona of 1896 to those of 1885 and 1886 confirms the now recognized theory of periodic changes in the corona in accordance with variations in the solar activity, as shown by sun spots.
2. The corona of 1896, as will be seen by the foregoing description, shows decided evidence of a connection between corona and prominences. This was indicated in 1893, but is still more striking in 1896.
3. The corona of 1896 shows the hitherto unperceived features of dark streams or veins, which it seems impossible to regard as merely spaces between bright rays. The only features I have hitherto seen, which to any degree resemble them, are the comet-like markings on the E. side of the corona of 1871. The dark bordering or outline to some of the prominences I have not observed on any other eclipse photographs.

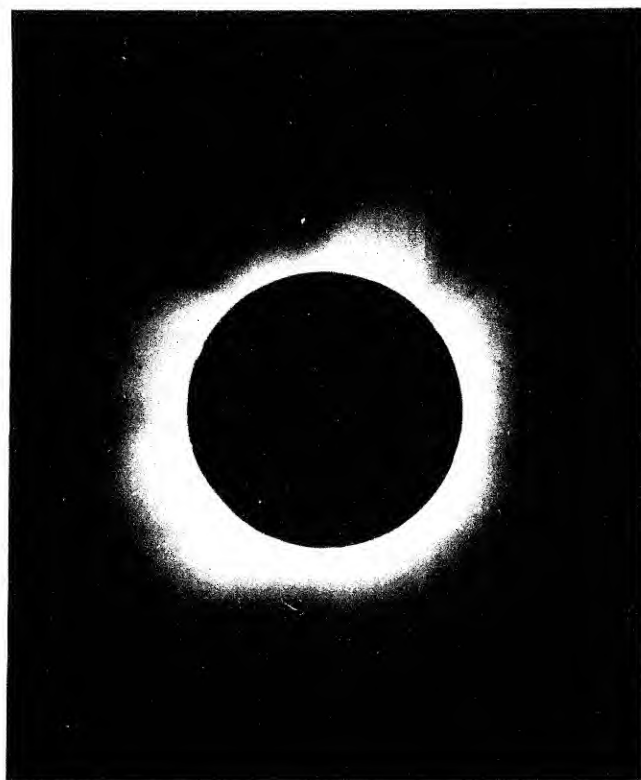
1



2



3



4



1 EXPOSURE 5 SECS
BEGINNING OF TOTALITY
3 EXPOSURE 40 SECS
30 SECS IN TOTALITY

2 EXPOSURE 15 SECS
10 SECS IN TOTALITY
4 EXPOSURE 2 SECS
1 MIN 15 SECS IN TOTALITY

N.

Sun

Sun

E.



W. H. Wesley, del.

S.

Woodburytype-Gravure.

TOTAL ECLIPSE OF SUN, AUGUST 9, 1896.

1



2



3



4



1 EXPOSURE 5 SECS
BEGINNING OF TOTALITY

3 EXPOSURE 40 SECS
30 SECS IN TOTALITY

2 EXPOSURE 15 SECS
10 SECS IN TOTALITY

4 EXPOSURE 2 SECS
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W. H. Wesley, del.

S.

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TOTAL ECLIPSE OF SUN, AUGUST 9, 1896.